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Mono Composite Leaf Spring – Design and Testing

KEYWORDS: Composite leaf spring, Glass fiber reinforced plastic, Static load analysis, Experimental test.

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ABSTRACT *Current issue in Automobile, Aerospace, Marine etc. is to reduce the weight of product by maintaining its strength. In Automobile sector Leaf spring of steel material which is used in suspension system can be replaceable by composite material due to its high strength to weight ratio and the composite materials have more elastic strain energy storage capacity. The objective of this paper is to present a composite material as an alternative to the conventional steel leaf spring by experimental tests.*

INTRODUCTION

The Leaf spring is used in the automobile sector since long time. Still Leaf spring is used for the suspension purpose due to its advantages over the helical spring. The advantage of Leaf spring over helical spring is that the ends of the springs are guided along a definite path so as to act as a structural member in addition to shock absorbing device. Leaf springs are still used widely in a variety of automobiles to carry axial loads, lateral loads and brake-torque in the suspension system. Leaf spring manufactured by conventional material carries heavy weight e.g. Leaf spring of Maruti Omni carries 16 kg load. Hence forth suspension system is an area, where we may use composite material to reduce the weight without compromising the strength. This paper mainly focuses on the alternative to conventional material of leaf spring, fabrication processes of composite material.

Several papers were devoted to the application of composite materials for automobiles some of them are as follows: 1) G. Shiva Shankar and S. Vijayrangan showed that introduction of Glass fiber/epoxy material may reduce the weight of leaf spring without any reduction in strength. 2) M. Venkatesan, D. Helmen Devaraj showed about 85% loss of weight due to use of composite material by comparing results from ANSYS software.

SPECIFICATION OF PROBLEM:

In this analysis the conventional steel multi leaf spring of Maruti Omni (8seater) is tested for static load condition analytically and results are compared with an experimental test. With the results we shall check the replacement of steel multi leaf spring by composite mono leaf spring. Here we are going to compare weight to strength ratio of both.

DESIGN AND DEVELOPMENT:

Considering, mounted leaf spring as a Simply Supported Beam and only master leaf is selected for calculations.

In this work we are using composition of Glass fiber-7781, and epoxy resin. A major advantage of using Fiber grate Composite Structures fiberglass products is the ease of fabrication — sawing, grinding, drilling and machining is similar to working with wood, metals and plastics. Due to its advantages, we have considered the Glass as a material for fibers.

DESIGN PARAMETERS OF STEEL LEAF SPRING:

Material selected = Steel (55Si2Mn90)
Tensile strength (N/mm2) = 1962
Yield strength (N/mm2) =1470
Young's modulus E (N/mm2) = 2.1×10^5
Design stress ($\sigma_{b)}$ (N/mm2) = 653
Total length (mm) =1025
The length between the axle seat and the Front eye (mm) = 512.5
Camber height (mm) = 40.5
Spring rate (N/mm) = 32
Normal static loading (N) = 500
Spring thickness (mm) = 5
Spring width (mm) = 50
Spring weight (kg) = 08

DESIGN PARAMETERS OF COMPOSITE LEAF SPRING:

Material combination selected = Glass fiber-7781 and epoxy resin
Tensile modulus of Fiber along X-axis = 70 GPa
Tensile modulus of matrix along X-axis = 2.8 GPa
Volume of fiber in composite material = 50.11%
Volume of matrix in composite material = 49.89%
Tensile strength of the material, MPa = 900
Compressive strength of the material, MPa = 450
Mass density of the material, kg/mm3 = 2.6x10-6
Total load on the spring = 500 N
Spring weight (kg) = 0.9

CALCULATIONS:

Tensile modulus of composite material along X-axis= $E_1 = (E_f.V_f) + (E_m.V_m)$

Where, f = fiber, m = matrix, V = volume in composite.

E_1 = 34.474GPa

Sr. No.	Parameter (For uniform width)	Formulae	Steel	Composite
1	Maximum stress induced, σ_{max} (MPa)	$\frac{3FL}{bt^2}$	615	615
2	Maximum deflection, δ_{max} (mm)	$\frac{2FL^3}{Ebt^3}$	102.56	590.49

DEVELOPMENT OF PATTERN:

For fabrication of composite leaf spring the pattern is required. The pattern is made up of wood. The pattern dimensions are calculated by the dimensions of designed leaf spring.

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FABRICATION OF COMPOSITE MONO LEAF SPRING:
For fabrication of composite spring, we should have to use the composition of Fibers and Matrix. For present work we have used Glass fiber and Epoxy as a resin.

The constant cross section is selected to design due to its capability of mass production and to accommodate continuous reinforcement of fibers and also it is quite suitable for hand lay-up technique. Some methods of fabrication are as follows:

1. Pultrusion
2. Resin Transfer Molding (RTM)
3. Vacuum Assisted Resin Transfer Molding (VARTM)
4. Hand Layup- Open Molding Process
5. Compression Molding
6. Filament Winding

Here we are going to fabricate the leaf spring by Hand layup method. Hand layup method is adopted for fabrication due its advantages over the others. Tooling cost is low, No skilled worker is required, large items can fabricate, easy method than others etc.

HAND LAY UP METHOD:
1. Cutting of Fibers:
For this project we had taken the fiber material as E-Glass (7781). This fiber is available in sheet format. This fiber sheet is cut by composite scissor. The dimensions for cutting lamina are

1200(mm) x 65(mm).

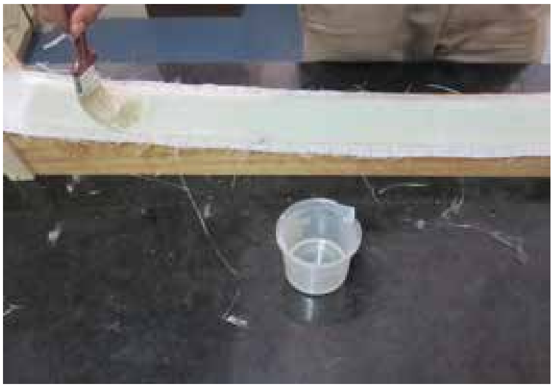
2. Preparation of matrix(Epoxy):
In preparation of matrix we used two solution named resin and hardener. The resin is Epolom 5015 and hardener was Polyoxyalkelenamine. The material is selected as per guidance of material expert.

3. Fabrication:
First take the wood pattern, on which keep Plastic Bagging first as per the dimensions available. On the bagging keep Peel Ply of same dimension. The bagging is required to leak proof fabrication or the resin should not be in contact with the pattern. Resin is sticky in nature and hence the contact to pattern should avoid. Peel Ply is required for the finishing of the required component.

Now, keep first sheet of fiber, apply the matrix over the first fiber sheet. Apply matrix such that all air should be removed. Now, keep second lamina over the applied matrix and again apply matrix as discussed above. Continue this process for till the last fiber sheet.

After completion of 18 layers keep above it again Peel Ply and Plastic Bagging.

After applying matrix keep this arrangement to dry at least for 24 hrs. The curing time of this matrix is 24 hrs.



4. The final output is as follows:

5. After 24 hrs. remove the peel ply and bagging. Now to get required dimensions it should be cut by water jet cutting.

EXPERIMENTAL TESTING OF LEAF SPRINGS:
We have done experimental test for static analysis in PRAJ Metallurgical Laboratory, Pune.

a. Experimental set-up of steel leaf spring:

b. Experimental set-up of composite leaf spring:

EXPERIMENTAL TESTING RESULTS:
Load is applied till the spring become flat.

Sr. No.	Parameter (For uniform width)	Load (N)	Stress induced, σ_{max} (MPa)	Deflection, δ_{max} (mm)
1	Steel	500	615	42.3
2	Composite	35	43.05	48.5

Maximum load carried by steel leaf spring is 770.28 N at deflection 72.6 mm.

Analytically, spring deflection of composite spring at load 35 N by putting values in above equation is 41.33 mm.

The tensile strength of composite leaf spring is 900 MPa, hence maximum stress induced is under the limits. Maximum deflection is allowed only 40.5 mm, but induced deflection is too high. So by changing thickness we shall get require output. If we increase thickness up to 12 mm, we shall get deflection in limit.

Calculate analytically, by taking thickness 12 mm and keep other dimensions same as before,

Maximum deflection = δ_{max} = 36.68mm

CONCLUSION:
1. The results of the analytical and experimental analysis are almost same; hence we may predict the dimensions of leaf spring by analytical method.
2. To use the composite material instead of steel, we have to change dimensions. Here we have changed the thickness from 5 mm to 12 mm. For safe side the thickness should be 14 mm.
3. The weight reduction is 88%.
4. The composite material is having chipping resistance problem, but it may avoid by using Carbon fibers.

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